Pre- and post-night shift mental performance of registrars in a department of anaesthesiology

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

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Declaration

I, Hilda Tsungayi Masvikwa, declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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Abstract

Background

Anaesthetists are required to preserve accuracy and fast decision making skills even when sleep-deprived. Studies have shown that mental performance is negatively affected by sleep deprivation and results in more fatigue-related errors. In South Africa, there is limited research on the impact of fatigue and its association with a decline in mental performance among anaesthetists. This study investigated, using neurocognitive tests, the effect of sleep deprivation on the mental performance of anaesthetists in the Department of Anaesthesiology at the University of the Witwatersrand (Wits).

Methods

A prospective, contextual and comparative research design using convenience sampling was followed. The post-night shift scores of 50 anaesthesia registrars were assessed using three neurocognitive tests and compared with their pre-night shift scores from August to October of 2019. The neurocognitive tests used were the Stroop Colour and Word Test, the Trail Making Test and the Continuous Performance Test. The individual circadian body clock of registrars was described using the Morningness-Eveningness Questionnaire.

Results

Registrars had decreased attention and committed more errors of commission during the Continuous Performance Test ($p=0.04$). However, their short term memory was preserved as they had shorter completion times post-night shift in the Stroop Colour and Word Test and Trail Making Test. The intermediate body clock type (50%) was the most common, followed by morning type (40%), and evening type (10%). The only significant variance in mental performance between the body clock types was found in the evening group, who made more errors in the Continuous Performance Test.

Conclusion

Mental performance is affected by sleep deprivation and possibly individual circadian rhythms. Post-night shift, Wits anaesthesia registrars were able to preserve speed and memory recall but committed more attentional errors. The evening body clock type group made more attentional errors than the morning and intermediate groups during the Continuous Performance Test.

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Abbreviations

app	application
PER 3	Period circadian protein homolog 3
UK	United Kingdom
Wits	University of the Witwatersrand

Statement

This research report consists of a literature review, draft article, study proposal and appendices. The study proposal is included for background reference and is not for examination.

The formatting of this research report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article may differ from the author guidelines of the South African Journal of Anaesthesia and Analgesia (SAJAA), the journal to which it is intended to be submitted, in order to comply with the university's style guide.

Section 1: Review of the literature

1.1 Introduction

In this chapter, the literature pertaining to the physiology of sleep, sleep homeostasis and the disruption of sleep homeostasis by shift work is reviewed. The neurocognitive and health-related consequences of sleep deprivation and individual susceptibility to shift work are analysed. Fatigue, microsleep and guidelines for anaesthetists are discussed. The effects of sleep deprivation on the anaesthetists' cognitive performance, decision-making, technical and non-technical skills are compared and contrasted to the normal cognitive performance required by anaesthetists to provide safe anaesthesia. Tests and assessment tools for neurocognitive function are discussed.

Sleep deprivation and its association with cognitive decline have been a concern within the medical fraternity for over four decades. In 1978, Cooper et al (1) described fatigue-related anaesthetic errors and found that human elements contribute to "preventable anaesthesia mishaps," which included a lack of experience, inadequate proficiency with the use of anaesthetic machines, poor communication, inattention and fatigue, and were the major causes of anaesthetic errors (1). In 2010, Cooper was part of the compilation of the International Standards for a Safe Practice Of Anaesthesia. These standards encouraged a sufficient number of anaesthetists to prevent staff fatigue (2).

Some of the aforementioned medical errors can be fatal. For example, in 1984, Libby Zion, an 18-year-old girl, died within 24 hours of her admission to a New York hospital, while under the care of a sleep-deprived medical intern. This led to a civil case against the hospital and prosecution of the junior doctor in charge of her case. This incident led to the formation of the Bell Commission, which developed a set of recommendations for the working hours of resident doctors (3). One of the recommendations was that interns and residents work no more than an 80-hour workweek and must not have more than 24 hours of continuous work (4). Later in 2003, the Accreditation Council for Graduate Medical Education (5) in the United States of America formalised these recommendations in response to the Libby Zion case. Notwithstanding that these recommendations were a good initiative, Landrigan et al (6) reviewed the recommendations two years after they had been instated and found that the recommendations were implemented poorly, as 68.8% of residents were still working more than 80-hour workweeks (6). This, perhaps, may be due to the high global demand for doctors.

In South Africa the scarcity of medical doctors results in doctors working longer hours than permitted by the law. In 2012 an article by Erasmus (7) highlighted the challenges faced by junior doctors such as the biopsychosocial effects of long working hours, sleep deprivation, high risk of medical errors and potential litigation. The article noted minimal institutional and governmental support as a contributing factor to the challenges that doctors face (7). The dire effects of this lack of support was demonstrated in 2016, when a fatigued medical intern was involved in a motor vehicle accident, post-night shift, which resulted in the death of a civilian (8).

At present, no changes have been made to the working hours for doctors in South Africa. The current guidelines only outline recommend practices that cannot be enforced as law. Decisions regarding the regulation of working hours are thus left to the discretion of different governing bodies and institutions.

1.2 The physiology of sleep and sleep homeostasis

Sleep is a reversible state of unconsciousness during which humans have no response to visual stimuli and a decreased auditory threshold (9). Sleep is controlled by an intrinsic circadian clock which controls cognitive performance over the daily 24-hour cycle (10, 11). This circadian clock sets a natural cyclical rhythm which is controlled by the suprachiasmatic nucleus. These electrical influences are synchronised by light and melatonin, both of which cause a change in alertness and a phase shift in the cycle (10). The suprachiasmatic nucleus controls physiological and behavioural processes that involve sleep-wake cycles, mood changes, temperature and autonomic and endocrine homeostasis (11, 12).

Sleep is central to the antioxidant defence system as oxygen radicals are scavenged and removed from the body during sleep. Sleep deprivation leads to impairment of the antioxidant defence system, which leads to acute and chronic cognitive decline (13). Unscavenged free oxygen radicals cause reactive oxygen neuronal damage and have been implicated in psychiatric and sleep disorders, as neurons are vulnerable to free oxygen radicals (13, 14).

1.3 Disruption of sleep homeostasis by shift work and individual variation

Shift work is an important work schedule strategy which enables a medical institution to maintain continuous service, 24 hours a day. Night shifts have been shown to increase the risk of sleep disturbance due to the disruption of the circadian rhythm (12). The undesired result is the disruption of normal sleep homeostasis, which leads to short, poor quality sleep and excessive fatigue (13). Night shifts affect the light-dark cycle and the normal circadian rhythm, which is the natural cyclical sleep pattern. After a night shift, sleep is typically four hours shorter and of poorer quality due to nocturnal melatonin suppression (10). This sleep loss leads to sleep debt and an increased need for sleep.

Sleep debt cannot be repaid on an hour-to-hour basis, but only with time spent in Stages 3 and 4 of non-rapid eye movement sleep (9, 12). This means that a sleep debt of eight hours will require 16 hours of sleep to restore sleep homeostasis (10). This has been useful in formulating the recommendations stipulated in the Basic Conditions of Employment Act 75 (15), which discourages shifts that are less than 12 hours apart.

An individual’s circadian clock genes detect the rhythmic expression of the suprachiasmatic nucleus and are regulated via a feedback loop (10, 12). These individual circadian clock genes are genetic polymorphisms of the period circadian protein homolog 3 (PER3). This gene has been implicated in the regulation of circadian rhythms and sleep homeostasis (16, 17). Individual responses to sleep deprivation, fatigue and mental performance are influenced by different expressions of genes such as the PER3 gene (16). This results in individual differences in the ability to perform tasks and cognitive susceptibility to sleep deprivation. Landolt (16) found that evening phenotypes are more tolerant to night work and can sleep during the day while individuals who become fatigued earlier have been found to have long PER3 polymorphism and shift work intolerance (16).

Horne and Ostberg (18), developed a useful questionnaire which differentiates the evening phenotype from the morning phenotype (18). Bennet et al (19) assessed the individual differences in the influence of time of day on executive functions. The hypothesis was that the morning type, when tested at 08:00, and the evening type, when tested at 15:00, would result in more efficient executive functions such as attention and memory. However, no significant difference in errors was found during Conner's Continuous Performance Test. The consensus is yet to be reached on whether questionnaires such as the Morningness–Eveningness Questionnaire (18) can be used to determine better learning, testing and therapy times (19).

1.4 Consequences of shift work and sleep deprivation

Night shifts are an essential and inescapable part of healthcare provision and possibly the most physically draining aspect of registrar training. The Association of Anaesthetists of Great Britain and Ireland (20) acknowledges The European Commission's Working Time Directive, which states that a shift worker can only work up to 58 hours per week. They must also receive 48 hours of rest every 14 days and 1 day of rest every 7 days (20).

In South Africa, registrars are required to do 80 overtime hours per month (21). South African registrars are therefore working longer night shifts than their international counterparts. Registrars report feeling tired while working and many experience non-refreshing sleep and chronic fatigue (22). Therefore, there is a need to quantitatively assess whether long working hours and the resultant sleep deprivation can be implicated in cognitive decline, which may have an adverse effect on the ability to provide adequate patient care.

Shift work is associated with Shift Work Sleep Disorder and sleep deprivation. Shift Work Sleep Disorder is a clinical circadian rhythm disorder characterised by fatigue, insomnia and sleepiness during early morning and night-time work (23). This is due to the disruption of the sleep-wake cycle and the reduction of recovery times between shifts. Shift workers also suffer from sleep disorders such as insomnia, sleep apnoea and poor-quality sleep which predisposes them to chronic fatigue (24).

Sleep deprivation causes cognitive decline, neurobehavioral changes and impairment of the antioxidant defence system, which has been linked to chronic diseases (23).

Cognitive decline, in the form of poor concentration and microsleep (a spontaneous episode of sleep lasting up to thirty seconds), was shown to increase the risk of accidents due to human error in shift workers, truck drivers, medical residents and pilots (12). In 2005, Barger et al (25) showed that long working hours increase the risk of motor vehicle accidents as doctors commute home post-night shift and are sleep-deprived (25). A 2017 survey on anaesthetists in the United Kingdom showed that 57% of them had either had an accident post-night shift or a near miss on their way home (26). Shift workers also experience neurobehavioral disturbances such as depression, irritability, poor concentration. This mixed symptomology shows that chronic sleep deprivation affects many different bodily functions (23, 24).

In a review of the health consequences of shift work and its relationship to sleep deprivation, chronic disease and medical errors, Kecklund and Axelsson (24) found that shift work has not been identified as a definite cause of chronic disease. However, Ozdemir et al (13) found that sleep-deprived shift workers had higher levels of oxidative stress. Oxidative stress is a leading cause of acute and chronic disorders. It occurs when the removal of oxygen free radicals is superseded by systemic oxygen radical secretion (13, 27). This results in increased cortisol levels which have been linked to cognitive impairment, immunological and metabolic changes and neurological disorders such as Shift Work Sleep Disorder (27).

1.5 Fatigue, the anaesthetist and microsleep

“Fatigue is a state of physical or mental weariness characterised by a lessened capacity for work and reduced efficiency of accomplishment” (12). The global prevalence of fatigue levels among anaesthesia registrars has not been determined, however, there are certain countries that have released related data. Gregory and Edsell (12) state that the prevalence in the Netherlands and the United States of America is 84% and 17%, respectively (12). In 2016 at the University of the Witwatersrand, Sanders et al (22) assessed anaesthetists’ perception of their sleepiness at work using the Epworth Sleepiness Scale and any errors they could attribute to sleep deprivation. All of the participating anaesthetists reported that they had insufficient sleep due to their work schedule, to varying degrees (22). In 2017, a national survey showed that 70% of trainee anaesthetists in the United Kingdom reported that fatigue affected their physical and psychological well-being (26). Anaesthetists often feel tired while working and they recognise their susceptibility to making errors due to their fatigue.

A vigilant anaesthetist, who can remain alert and "sleeplessly watchful", is vital for the safe administration of anaesthesia (28). Anaesthetists are required to have sustained vigilance and attention to perform repetitive tasks and this makes them more prone to errors when fatigued (28). Environmental factors such as enforced silence, unscavenged anaesthetic volatiles, dim light and monotony, may reduce vigilance and make anaesthetists more prone to microsleep (12). The nature of microsleep is that the individual will be unaware of their loss of consciousness. It can occur at any time irrespective of the task at hand, age or experience. The brain malfunctions and is unable to receive sensory input during microsleep (12).

Lockley et al (29), in a study of 20 Harvard intensive care unit interns, linked reduced working hours (less than 80 hours per week) to less attentional failures. These attentional failures (slow eye-rolling movements) occurred during episodes of wakefulness and were identified by continuous electrooculography. The interns that recorded sleeping 5.8 more hours per week had less slow eye-rolling movements compared to those that had longer work hours and less sleep. In occupational settings, the presence of slow eye-rolling movements parallels subjective sleepiness, microsleep and impaired neurocognitive performance. It is a sign of fatigue and increases the risk of errors which may result in medicolegal consequences (29). Common signs are slow eye-rolling movements, eye closure, head nodding and reduced blinking (12).

There is a growing concern that medical errors are occurring and going undetected by anaesthetists. Sanders et al (22) showed that 48.6% of anaesthetists surveyed admitted to making errors due to sleepiness. Fatigue, long working hours, shift work and stress are associated factors in the incidence of percutaneous injuries in medical personnel (22). Fatigued anaesthetists are not only dangerous to their patients but also to themselves.

1.6 Cognitive performance and medical errors

There is a higher incidence of errors in medical specialities – such as anaesthesiology – that have high time pressure, data uncertainty, fatigue and stress (30, 31). Sleep-deprived anaesthetists are more prone to underestimate their level of cognitive impairment, especially when they are overly familiar with the task and the task is monotonous (17, 32).

Ideally, anaesthetic errors should be 0%, however, this is not the case due to human susceptibility to cognitive errors. In 2000, a retrospective review of the Australian Incident Monitoring data collection system by Morris and Morris (33) revealed that 2.7% of critical anaesthetic incidents that occurred from 1987 to 1997 were fatigue-related (33). Common errors were syringe swaps, “wrong drug” errors and under- or overdosing of pharmacological agents. These incidents were related to inattention and decreased vigilance (33). These results were similar to those found by Cooper et al (1) in 1978. This shows that the causes of human errors have not been adequately addressed.

1.7 Guidelines and recommendations for anaesthetists’ working hours

The American Society of Anesthesiologists (34) recognises that fatigue is multifactorial in its causes, thus the onus is on individual organisational structures to institute policies which are unique to their practice. The American Society of Anaesthesiologists urges education, support and flexibility of policies to accommodate a fatigued anaesthetist (34).

The Association of Anaesthetists of Great Britain and Ireland (20) limited weekly working hours to 48 hours taken over 17 weeks. After the death of an anaesthetist who fell asleep while driving home after a night shift, The Royal College of Anaesthetists and The Association of Anaesthetists of Great Britain and Ireland formed a joint initiative (35). They produced materials to identify and counteract fatigue which were made available to anaesthetists through their website.

Compensatory measures to stay awake such as caffeine stimulants, nap-taking, shorter shifts, bright lights, physical activity and snacking are recommended and encouraged (35). In addition, The Association of Anaesthetists of Great Britain and Ireland recommend education on sleep hygiene, making restrooms available and the adjustment of work routines; these are some of the interventions implemented to mitigate the adverse effects of sleep deprivation (20).

The Australian and New Zealand College of Anaesthetists does not recommend the use of caffeine and stimulants to counteract fatigue. The Australian and New Zealand College of Anaesthetists advocates designing the work schedule to counteract the effects of fatigue, by instituting shorter work hours, rest periods and educating staff on sleep hygiene (36).

Registrars at the University of the Witwatersrand work 16-hour night shifts, up to five times a month, with overtime compensation. The Basic Conditions of Employment Act 75 (17) exempts workers from night shift work that exceeds 12 hours, if they are financially compensated. However, the South African Society of Anaesthesiologists (SASA) (37) discourages night-time work longer than 12.5 hours as it contributes significantly to the risk of decreased vigilance, occupational hazards or medical error.

SASA provides a list of corrective strategies, which include limiting working hours, adequate numbers of staff, improvements to the work environment and fatigue alleviation routines. The onus is placed on the anaesthetists to evaluate their fatigue levels and assess whether they will be able to undertake their clinical duties without causing patient harm. Given the limited information available, and drawing from guidelines in other countries, SASA suggests that on-call duty of more than 17 hours is to be discouraged, and duty exceeding 24 hours is prohibited (37).

It is clear from the guidelines set by these international and national anaesthesiology organisations, that their purview cannot go beyond making recommendations. They are cognisant of the different patient populations, resource allocation and policies of different countries. They agree with the need to empower anaesthetists to assess their fatigue and their responsibility to opt to relieve themselves from their duties for their well-being and that of the patients.

1.8 Sleep deprivation and mental performance in anaesthetists

Mental performance and executive cognitive performance are used interchangeably in the literature and comprises vigilance, psychomotor and executive cognitive functions, including but not limited to, memory, attention and logical reasoning (38). Sleep deprivation has been shown to cause a decline in mental performance due to changes in the circadian rhythm (38). Alterations in neuropsychological processes such as attention, memory and executive cognitive function will lead to changes in mental performance (38).

Attention, a component of mental performance, deteriorates during periods of extended wakefulness and after an acute restriction of sleep (39, 40). After a period of wakefulness of 17−19 hours, the performance deficit is equivalent to a blood alcohol content of 0.05%, the drink-drive limit in the United Kingdom (41). Sleep loss results in global deficits in arousal and variability in attention, especially during monotonous tasks (42). Following sleep loss, mental performance becomes highly variable and lends itself to errors (43). A meta-analysis of sleep loss studies in sleep-deprived adults showed a decline of mental performance of 1.34 standard deviations below the mean of the control groups (43). This decline has been attributed to the breakdown of intercortical connections which results in decreased activity in the frontoparietal regions of the brain, which is responsible for attention and vigilance (17).

The negative effects of sleep deprivation on memory were tested by Saricaoglu et al (44). They investigated the effect of day and night shifts on the attention and memory of anaesthetists using the Auditory Verbal Learning Test and Visual Aural Digit Span Tests. The test scores of the anaesthetists deteriorated after the night shift, suggesting that sleep-deprived anaesthetists may have impaired memory and attention after a night shift (44).

Executive functions are cognitive functions that enable the capacity to initiate, programme and control behaviour (11). Cognitive functions are divided into rational and non-rational. Non-rational cognitive factors such as emotion, overconfidence, framing, preferences, memory-shifting, feedback, heuristics, anchoring, loss aversion and bias are components of executive function which are negatively affected by sleep loss, whereas rational cognitive functions are not (45).

Anaesthetists rely heavily on their executive functions as they are required to plan, solve new problems and make decisions under intense pressure with high levels of stress and fatigue (46). Decision-making, an executive cognitive function, is a dual-process model which was originally postulated by Evans (45) and described in Croskerry et al (47).They postulated two types of thought processes. Type 1 is the intuitive process which overrides toggling and calibration and results in an unexamined decision. Type 2 is the analytical process which allows for calibration and results in a more examined decision. For example, the Type 2 (analytical) processes required to administer correct drug dosages, are more susceptible to insufficient sleep whereas the Type 1 (intuitive) processes are preserved, as shown by Samkoff and Jacques (48). The authors found that sleep-deprived doctors were able to intuitively react to medical crises and situations. However, they were unable to sustain vigilance in routine and repetitive tasks and were susceptible to drug dose errors (48). This is because the Dual Process Model of Reasoning requires correct pattern recognition at the beginning of the decision-making process (46). Sleep deprivation alters the dual process of reasoning and may lead to incorrect decision-making which may negatively affect patient outcomes (46).

Executive functions, attention, analytical process and working memory are central to decreases in cognitive function when sleep-deprived (11, 39).

1.9 Effect of sleep deprivation on anaesthetists' technical and non-technical skills

Anaesthetists are required to preserve both intuitive and analytical processes as their decision-making process must result in action. The skill component of an anaesthetist's mental performance is divided into technical and non-technical skills.

Technical skills are procedural, including but not limited to intubation, intravenous line cannulation and peripheral nerve blocks. The repetition of analytic processes until they become automatic is the basis of technical skill acquisition (49). In obstetric anaesthesiology, Aya et al (50) found that the risk of unintentional dural puncture when placing an epidural increased by a factor of six during night shifts compared to day shifts (50). This suggests that technical skills which use fine motor skills may also be affected by sleep deprivation. Sleep deprivation leads to an increase in errors during the performance of technical skills such as simulated driving (49) and anaesthetists performing intubations (51). Murray and Dodds showed that anaesthetists who had undisturbed sleep were more vigilant whilst using a driving simulator than those anaesthetits who had disturbed sleep (52).

“Non-technical skills are the cognitive, social, and personal resource skills that complement technical skills” (49). They contribute to safe and effective task performance. The non-technical skills required by anaesthetists to provide quality care are teamwork, situation awareness, task management and decision-making (49, 53). Neuschwander et al (49) assessed the intraoperative non-technical skills of anaesthetists using a simulated crisis scenario (49). The results suggested that sleep deprivation is associated with impaired teamwork, sleepiness and decreased confidence in anaesthetic skills (49).

There is a need to quantify the degree of cognitive impairment resulting from sleep deprivation using neurocognitive tests (17). Neurocognitive tests should be easy to perform, brief, replicable and must test attention and working memory over time (54). The tests must be sensitive (able to show significant levels of variation in performance) and specific (unaffected by variables that may impact performance) (55). The tests must have concurrent and predictive validity: i.e. they must be able to measure cognitive decline and predict the future operational capacity of the anaesthetists. Tests must be able to measure the same ability in all individuals tested, showing reliability and generalisability (57). Sleep research must factor in the many variables involved in fatigue and decline in cognitive performance, such as circadian rhythm and individual variances.

Not many tests have been done on medical doctors compared to other shift workers like nurses (56). A systematic review by Mansukhani et al (57) on sleep deprivation in medical residents found that working for longer than 10 hours, or a working week of more than 60 hours, lead to lower quality performance among doctors. This decline in mental performance was measured using neurocognitive tests and a simulation laboratory to assess technical skills (57).

Balkin et al (55) found that performance in tests that are monotonous like the STISIM Driving Simulator and Wilkinson's four-choice reaction time test were the most sensitive to sleep deprivation as they required constant attention (55). Whereas tests that test executive function, such as logical reasoning, are the least sensitive to sleep loss (55, 58). In 2006, Griffiths et al (59) tested the global cognitive function of pre- and post-night shift anaesthetists using five subtests of the Wechsler Adult Intelligence Scale. There was no significant difference in the speed of monitoring, memory and learning accuracy but there was a significant decline in an anaesthetist's ability to detect errors (59). Suozzo et al (60) in 2011 showed a decline in the attention and memory of medical registrars using neurocognitive tests (60). The medical residents did poorly in the post-night shift Trail Making Test, which is similar to the results obtained by Leonard et al (61).

Simulation laboratories have been used to test the mental performance of sleep-deprived anaesthetists engaged in technical and non-technical skills. Howard et al (51) assessed the technical skills of 12 anaesthesia residents performing a four-hour anaesthetic on a simulated patient, the morning after normal sleep and after being sleep-deprived for at least 25 hours. Psychomotor and vigilance tests showed decreased mental alertness and performance, although clinical performance was similar between the two groups (51). In 2017, Neuschwander et al (49) found that the non-technical skills of anaesthetists in a crisis management situation were negatively affected by fatigue. The non-technical skills scale was used to assess the anaesthetists' ability to engage in teamwork, task management, situation awareness and decision-making. The results only showed a significant difference in teamwork in the group that was sleep-deprived (49).

1.10 Tests assessing neurocognitive function

There are numerous neurocognitive tests available for the assessment of mental performance. This review will focus on the Stroop Colour and Word Test, the Trail

Making Test for executive function and psychomotor skills and the Continuous Performance Test for sustained attention and vigilance.

The first neurocognitive test to be developed was the Stroop Colour and Word Test in 1935 (62). The cognitive processes tested were simple and complex attention, executive problem-solving, abstract reasoning and self-regulation. In 1991, Strauss et al (63) validated the test. This study will use the Stroop smartphone application (App.) developed by Bajaj et al (64) to screen for cognitive impairment (64). The Stroop smartphone application fulfilled the criteria for a neurocognitive test (55, 64). The validation cohort showed 90% specificity and 78% sensitivity. The application was found to be reliable, valid, brief and suitable to screen for minimal hepatic encephalopathy (64). The Stroop Colour and Word Test has not always been found to be sleep sensitive in medical personnel. In 1998 Leonard et al (61) found a significant decline in the post-night shift scores of medical registrars whereas Patrick et al (65) found no significant change when comparing the results of rested vs sleep-deprived university students (65).

The Trail Making Test was created by Partington in 1938 and has been used for neurocognitive assessment since its conception (66). It is a simple, quick test which tests a wide variety of cognitive processes such as attention, working memory, psychomotor speed and most importantly, the ability to modify and implement a plan of action (67). This cognitive processing is essential to anaesthetists. The Trail Making Test is sensitive to sleep deprivation, as it has shown decreased mental performance scores in post-night shift anaesthetists (35, 61). This makes it a suitable test for a sleep-deprived anaesthetist. Leonard at el (61) tested junior doctors and found that they had a statistically significant fallout in their mental performance after a 32-hour work shift. Puri et el (68) also found a significant decline in the Trail Making Test scores of sleep-deprived anaesthesia registrars. This showed a decline in psychomotor and cognitive function.

The Continuous Performance Test was developed in 1956 and measures sustained and selective attention, vigilance and impulsivity (69). It is sensitive to cognitive decline in a wide range of shift workers such as doctors, and pilots (70). In sleep-deprived participants, mean error scores are elevated and correct response scores were lowered (69) and the accuracy of response was shown to be spared at the expense of speed (71). However, Rollison et al (72) found no statistically significant difference in the pre- and post-night shift mental performance in medical interns using the Continuous Performance Test. The reasons for these unexpected findings could have been due to the small sample size, learning effect and high innate cognitive abilities of medical personal (72).

Few studies on the effects of sleep deprivation on anaesthetists have been conducted using neurocognitive tests. The results of these studies have been inconclusive in terms of finding a statistically significant correlation between sleep deprivation and decline in mental performance across the tests conducted. These varied results may be due to the numerous variables associated with sleep, as well as the varied approaches to conducting sleep research. Thus implementation of guidelines such as education on sleep hygiene, mandatory breaks amongst others in individual institutions will have more of an impact in mitigating the effects of sleep deprivation on mental performance than relying on the literature available.

1.11 Summary

In this chapter, the literature review was presented. The following topics were discussed: the physiology of sleep, sleep homeostasis and the disruption of sleep homeostasis by shift work. The neurocognitive and health consequences of sleep deprivation and individual susceptibility to the negative effects of shift work were also discussed. Fatigue and the anaesthetist, microsleep and the guidelines around the duration of shift work to prevent the negative cognitive effects of sleep deprivation on the practice of anaesthesia were reviewed. The effects of sleep deprivation on cognitive performance and decision-making were compared and contrasted to the normal cognitive performance required by anaesthetists to provide safe anaesthesia. Tests and assessment tools for neurocognitive function were also discussed.

1.12 References

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All articles should include an abstract. The structured abstract for an Original Research article should be 300 words or less and should consist of four paragraphs labelled Background, Methods, Results, and Conclusions. It should briefly describe the problem or issue being addressed in the study, how the study was performed, the major results, and what the authors conclude from these results. The abstracts for other types of articles should be no longer than 230 words and need not follow the structured abstract format.

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Cite references in numerical order in the text, in superscript format (Format> Font> Click superscript). Please do not use brackets or do not use the foot note function of MS Word.

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The following are sample references:

1. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process: volume assessment by 3-dimensional

re construction by high-resolution CT scanning. Otolaryngol Head Neck Surg. 2005 Mar;132(3):429-34.

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9. All photographs must be at 300dpi and clearly marked according to the figure numbers in the text. (Figure 1, Table II, etc.)
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11. Figure numbers: Arabic, table numbers: Roman.

Section 3: Draft article

Pre- and post-night shift mental performance of registrars in a department of anaesthesiology

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Keywords: pre- and post-night shift mental performance, neurocognitive tests, anaesthetists

Abstract

Background

Anaesthetists are required to preserve accuracy and fast decision making skills even when sleep-deprived. Studies have shown that mental performance is negatively affected by sleep deprivation and results in more fatigue-related errors. In South Africa, there is limited research on the impact of fatigue and its association with a decline in mental performance among anaesthetists. This study investigated, using neurocognitive tests, the effect of sleep deprivation on the mental performance of anaesthetists in the Department of Anaesthesiology at the University of the Witwatersrand (Wits).

Methods

A prospective, contextual and comparative research design using convenience sampling was followed. The post-night shift scores of 50 anaesthesia registrars were assessed using three neurocognitive tests and compared with their pre-night shift scores from August to October of 2019. The neurocognitive tests used were the Stroop Colour and Word Test, the Trail Making Test and the Continuous Performance Test. The individual circadian body clock of registrars was described using the Morningness-Eveningness Questionnaire.

Results

Registrars had decreased attention and committed more errors of commission during the Continuous Performance Test ($p=0.04$). However, their short term memory was preserved as they had shorter completion times post-night shift in the Stroop Colour and Word Test and Trail Making Test. The intermediate body clock type (50%) was the most common, followed by morning type (40%), and evening type (10%). The only significant variance in mental performance between the body clock types was found in the evening group, who made more errors in the Continuous Performance Test.

Conclusion

Mental performance is affected by sleep deprivation and possibly individual circadian rhythms. Post-night shift, Wits anaesthesia registrars were able to preserve speed and memory recall but committed more attentional errors. The evening body clock type group made more attentional errors than the morning and intermediate groups during the Continuous Performance Test.

Introduction

In 1984, a fatigued junior doctor was implicated in the death of an 18-year-old, Libby Zion (1). This death led to the reduction of working hours for junior doctors in the United States of America with an acknowledgement that the doctor's sleep deprivation may have played a role in the death. However, in South Africa, doctors still work long hours, which may lead to an increase in the number of adverse events at the hands of sleep-deprived doctors (2, 3).

Sleep is a reversible state of unconsciousness which is regulated by the circadian rhythm (4, 5). Sleep homeostasis is the balance between sleep need (7 – 9 hours every 24 hours) and sleep debt (5). When sleep homeostasis is disrupted and an adult gets inadequate sleep, they develop an increased need to sleep. This is seen by an increased tendency to sleep (sleepiness) and a lack of mental focus as a result of a decline in physical and mental performance (fatigue) (6). If sleep homeostasis is not restored, a cumulative sleep debt occurs and if that is not repaid, sleep deprivation occurs (5).

The consequences of sleep deprivation are biopsychosocial such as hypertension, anxiety, depression and decline in mental performance (7). The psychological disturbances can be so severe that they are comparable to those seen in people with a blood-alcohol level above 0.05% (8). The hazardous effects of sleep deprivation have been studied in shift workers such as nurses, doctors, pilots, rail and truck drivers (9).

Long working hours, consecutive night shifts and inadequate rest periods have been shown to cause chronic shift work disorder, which is a result of protracted sleep deprivation (10, 11). Fatigue-related human errors are as a result of microsleep, inattention and decreased mental performance (12, 13). The effect of sleep deprivation on the mental and physical performance of individuals has been linked to individual circadian body clock types (14).

Anaesthetists are required to preserve intuitive and analytical processes as their decision-making process must result in rapid decision-making and action. Mental performance in anaesthetists has been characterised as employing non-technical skills such as vigilance, memory and logical reasoning and has been tested using neurocognitive tests, technical skills and simulation laboratories (15). It has been shown that both technical and non-technical skills are affected by sleep deprivation (16–18).

Night shifts are an essential and inescapable part of healthcare provision and possibly the most physically draining aspect of a registrar’s training. The South African Society of Anaesthesiologists (19) suggests that a night shift duty of more than 17 hours must be discouraged (19). In the Department of Anaesthesiology at the University of the Witwatersrand (Wits), registrars are contractually obligated by the Gauteng Department of Health to work 52 – 80 hours of overtime per month (20), which amounts to approximately five night shifts per month. However, in practice, some registrars report working up to seven night shifts a month and being fatigued throughout their training programme (21).

The fatigue levels of the registrars in the Department of Anaesthesiology at Wits as a result of sleep deprivation are known. Sanders et al (21) showed that 79.4% of anaesthetists admitted to experiencing microsleep while on a night shift and 57.9% admitted to daytime microsleep. The results showed that 48.6% perceived making fatigue-related medical errors, 41.1% reported fatigue-related percutaneous injury and 94.4% feared having motor vehicle accidents, post-night shift (21).

Wits anaesthesia registrars perceived themselves to be fatigued, and feared causing harm to themselves and also to their patients and others (21). Thus, there is a need to quantitatively assess the effect of sleep deprivation on these registrars’ mental performance and to confirm or alleviate their concerns. This study aimed to compare the pre- and post-night shift mental performance of registrars in the Department of Anaesthesiology at Wits, using three neurocognitive tests, namely the Stroop Colour and Word Test (22), the Trail Making Test (23) and the Continuous Performance Test (24).

Methods

A prospective, contextual, comparative research design with convenience sampling was used in this study. The approval to conduct this study was obtained from the Human Research Ethics Committee (Medical) and Graduate Study Committee of Wits.

The study population consisted of the 112 registrars working in the Department of Anaesthesiology. In this study, a convenience sampling method was used. Sample size was calculated using a study by Rollison et al (25). This study showed a pre-night shift mean score of 25.6 and a post-night shift mean score of 25.4 for the Continuous Performance Test with a pre- and post-night shift difference of effect size of 0.2. Assuming a 80% power, 5% significance level (95% confidence level) and a high pre- and post-night shift test score correlation of 0.9, the minimum sample size required for the study was 42 registrars. For this study, a margin of error of 5% and a 95% confidence level was assumed and a sample of fifty registrars representing 45% of the registrar population were enrolled, giving a power of >90%. Those who did not give consent were excluded, as well as registrars with known medical sleep disorders and those who were on medication that depressed or stimulated the central nervous system. Registrars with known attention deficits such as attentional-deficit/hyperactivity disorder or who had consumed coffee or energy drinks less than two hours before data collection were also excluded.

The study was conducted from August to October 2019 at Chris Hani Baragwanath Academic Hospital, Charlotte Maxeke Johannesburg Academic Hospital, Rahima Moosa Mother and Child Hospital and Helen Joseph Hospital, the four core training hospitals of the department training platform. Night shift commenced at 16:00 and the duration varied from 15.5 to 16 hours between the different hospitals.

Mental performance fluctuates during the day as it is linked to the diurnal variation of the circadian rhythm. It declines from 03:00 – 07:00 and 13:00 – 16:00 (5). However, the study was conducted between 15:00 – 15:40 and from 07:00 – 07:30, which was convenient for the participants as it was close to the shift change. All registrars were invited and informed consent was given prior to testing at their respective hospitals. The tests were conducted by one author (HM) in well-lit, quiet meeting rooms with a “Do not disturb” sign placed on the door.

The data collection tools that were used consisted of a questionnaire and three neurocognitive tests. The questionnaire had two parts comprising demographics and the freely available Morningness-Eveningness Questionnaire (26). The first part of the questionnaire included the following demographics: age, sex, year of registrar training, duration of sleep pre-night shift and duration of sleep post-night shift. The second part of the questionnaire was the seven-minute Morningness-Eveningness Questionnaire developed by Horne and Ostberg (26).

The innate body clock is gene-dependent and results in individual differences in sleep, vigilance and response to stimulants. The 19 questions aimed to determine if the mental performance of the participant is highest during the morning (early bird) or in the evening (night owl). Test scores of 59 and above indicate "morning type" and scores of 41 and below indicate "evening type". The "intermediate type" are those who score between 42 – 58 (26).

The three neurocognitive tests that were used are validated, freely accessible on the internet and permission to use the tests was granted from the developers. The tests were downloaded onto electronic tablet devices (Apple iPads™). The Stroop Colour and Word Test, developed by John Ridley Stroop (22), was used to test simple and complex attention, executive problem-solving, abstract reasoning and self-regulation. Bajal et al (27) developed the Stroop smartphone application (app). Participants are required to name the colour of the font of an incongruent word or symbol. This interference causes the naming of the colour to take longer and participants are more prone to errors. The duration of the test is user-dependent but most complete it in less than three minutes.

The Trail Making Test was developed by Partington (23) in 1949 and an app was produced by Simolabs. The test is used to test attention, working memory, psychomotor speed and ability to modify and implement a plan of action (9, 28). This test is sensitive to sleep deprivation, as it has shown poor scores in post-night shift internal medicine residents (9). The Trail Making Test consists of two parts. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the circles in ascending numerical order. In Part B, the circles include both numbers (1 – 13) and letters (A – L). A number must be joined to a letter in order, for example, 1 and A, 2 and B. There is one more number than there are letters.

The testing time is user-dependent and errors will increase the completion time. The test is abandoned after five minutes, but most complete it in less than three minutes (23).

The Continuous Performance Test, developed in 1956 (24), was adapted and used to measure sustained attention, vigilance and impulsivity (29). Various forms of this test are available. The Visual Attention Test (30), developed by the New York City Traumatic Brain Injury Center was used in this study. The test lasts seven minutes and the results are grouped into errors of commission and errors of omission. Attention span is the measure of the two types of errors, namely errors of commission (impulsive touching of the cat) and errors of omission (failure to touch any animal other than the cat) (30). In sleep-deprived subjects, mean error scores are elevated and correct response scores are lowered (31). Reaction time has been shown to decline to preserve the accuracy of response (32).

The data were analysed in consultation with a biostatistician using Stata version 14 (StataCorp, USA). Categorical variables were described using frequencies and percentages. Pre-night shift scores of each participant acted as the control (measured in time). The post-night shift score was compared to the control using the non-parametric Wilcoxon signed-rank test, as the assumptions for normality were not met. Comparisons between more than one group was done using the Kruskal-Wallis test. Following the Kruskal-Wallis test a Dunn's pairwise comparison with the Bonferroni correction was performed. A p-value of <0.05 was considered statistically significant.

Results

There are 112 registrars in the department and of these, 50 participated in the study representing 45%. Of all the registrars, 27 (54%) did not have additional sleep in preparation for night shift after waking up in the morning, 8 (16%) slept for 1 hour, 12 (24%) slept for 2 hours, 1 (2%) slept for 3 hours and 2 (8%) slept for 4 hours. During night shift, 20 registrars (40%) did not have sleep, 5 (10%) slept 1 hour, 10 (20%) slept 2 hours, 11 (22%) slept 3 hours and 4 (8%) slept 4 hours. The characteristics of the registrars are shown in Table I.

Table I: Characteristics of registrars

Characteristic	Number	Percentage
Age group (years)		
25–29	5	10
30–34	35	70
35–39	6	12
40–44	2	4
>45	2	4
Gender		
Male	19	38
Female	31	62
Year of registrar training		
First	11	22
Second	13	26
Third	14	28
Fourth	12	24

Table II shows the body clock type of the registrars.

Table II: Body clock of registrars

Body clock type	Number	Percentage
Morning	20	40
Intermediate	25	50
Evening	5	10

Table III shows the neurocognitive test scores and comparisons between pre- and post-night shift scores. The only statistically significant difference for the pre- and post-night shift tests was for the Continuous Performance Test for errors of commission, with more errors occurring in the post-night shift test than the pre-night shift test (p = 0.04).

Table III: Neurocognitive test scores of registrars

Neurocognitive test	**Time in seconds**			
	Median	**IQR**	**Range**	**P-value**
Stroop Test				
Pre-night shift	77.9	66.1–96.9	61.2–124.5	0.657
Post-night shift	76.8	66.6–110.5	63.7–121.8	
Trail Making Test				
Test A				
Pre-night shift	19.7	13.8–29	13.7–30.7	0.820
Post-night shift	18.5	13.9–29.5	13.6–43.2	
Test B				
Pre-night shift	46.3	25.2–81.4	17.1–97.8	0.07
Post-night shift	40.2	29.2–73.0	16.90–83.20	
	Number of errors			
	Median	**IQR**	**Range**	**P-value**
Stroop Errors				
Pre-night shift	1	0–2	0–5	0.618
Post-night shift	0.5	0–3	0–7	
Continuous Performance Test				
Errors of commission				
Pre-night shift	2.5	0–8	0–13	0.04
Post-night shift	4	0–11	0–14	
Errors of omission				
Pre-night shift	6.5	1–34	0–39	0.49
Post-night shift	6.5	1–35	0–129	

The registrars' performance in each neurocognitive test was compared with their body clock type (morning, intermediate and evening). Table IV shows the comparison between body clock types and the difference in the pre- and post-night shift scores. The Continuous Performance Test – errors of omission, found a significant difference between mental performance and body clock type. Registrars with the evening body clock type displayed more errors of omission in their post-night shift test scores when compared with morning (p= 0.014) and intermediate (p= 0.026) body clock type.

Table IV: Comparison between body clock types and difference in the pre- and post-night shift scores

Neurocognitive test	P-value
Stroop	0.980
Stroop Errors	0.846
Trail Making Test A	0.847
Trail Making Test B	0.834
Continuous Performance Test – errors of commission	0.334
Continuous Performance Test – errors of omission	0.031

Table V shows the comparison of the difference between pre- and post-night shift scores of the first-year to fourth-year registrars. A significant difference was found between the pre- and post-night shift scores for the Stroop and the Trail Making Test B among the first-year registrars compared to fourth-years only.

Table V: Comparison of the difference between pre- and post-night shift test scores and year of training

Neurocognitive test	P-values			
	First	Second	Third	Four
Stroop	0.033	0.331	0.507	0.347
Trail Making Test A	0.790	0.925	0.382	0.432
Trail Making Test B	0.010	0.777	0.248	0.158
Continuous Performance Test – errors of commission	0.472	0.528	0.057	0.579
Continuous Performance Test – errors of omission	0.194	0.329	0.361	0.158

Discussion

In South Africa, service delivery needs have resulted in long working hours for doctors (2). A negative consequence of overworked doctors was proven in a motor vehicle accident that occurred in Cape Town. It involved a fatigued post-night shift junior doctor and resulted in the death of a civilian (3). Anaesthetists are shift workers who work long hours while being required to accurately complete various cognitive and physical tasks under stressful conditions (33, 34). Overfamiliarity and the monotonous nature of some tasks make anaesthetists particularly susceptible to a fatigue-related decline in mental performance (35, 36), which can lead to adverse patient effects and occupational accidents such as needle stick injuries and motor vehicle accidents (37).

Mental performance in anaesthetists has been characterised as employing non-technical skills such as vigilance, memory and logical reasoning (13). The selection of the tests in this study was intentional and factored in cognitive processes which are required by anaesthetists and have been shown to be affected by sleep deprivation (15,17,18). Research must factor in the many variables involved in fatigue and decline in cognitive performance, such as circadian rhythm and individual variances.

In this study, no differences were found in the pre- and post-night shift scores in the Stroop Word and Colour Test and the Trail Making Test. The only significant decline in mental performance was shown as an increase in errors of commission during the Continuous Performance Test. The practice of anaesthesia is dynamic and although it requires fast memory recall and speed of thought processing (tested by the Stroop Colour and Word and Trail Making Test), there are times where it can be described as monotonous (tested by the Continuous Performance Test).

The Continuous Performance Test has shown that the longer and more repetitive the task, the greater the decline in mental performance when sleep-deprived (32). This was evident in this study as registrars made more errors of commission attentional errors, in the Continuous Performance Test, which was seven minutes long. However, registrars had faster scores in the Stroop Colour and Word Test and the Trail Making Test. This is contrary to some international studies (38, 39, 40,) which showed longer post-night shift completion scores for the Stroop Colour and Word Test and the Trail Making Test. This may suggest that although they performed the repeated task in a shorter amount of time, their accuracy had decreased as they committed more errors in the Continuous Performance Test. These three findings are important as Wits anaesthesia registrars seemed to sacrifice accuracy of task completion for speed of thought and memory recall.

Unfortunately, few studies have compared post-night shift scores to individual circadian rhythms. Bennet et al (14) found no significant difference when comparing mental performance and individual circadian rhythm differences. In this study, registrars with an evening body clock type displayed more errors of omission when sleep-deprived, post-night shift. The Stroop Colour and Word Test and Trail Making Test did not show a statistically significant difference in the mental performance of registrars when grouped into their body clock types.

The ability to perform tasks when sleep-deprived is demanded of Wits anaesthetists, but the accuracy of task completion has never been measured. The effects of fatigue on anaesthesia registrars have been reported but vary from country to country. In this study population, 48.7% of Wits anaesthesia registrars reported the perception of making fatigue-related errors (21), which was demonstrated by more post-night shift errors in the Continuous Performance Test, which was shown to be sensitive to sleep deprivation and body clock type. However, the faster post-night shift scores may reflect the adaptation of Wits anaesthesia registrars to their stressful work environment. Although they had a negative perception of their cognitive abilities when sleep-deprived (21), they showed an ability to overcome fatigue while performing shorter tasks. Through the Continuous Performance Test, perceived fatigue related mental decline was demonstrated as they were more prone to making fatigue-related attentional errors during a monotonous task. This not only has implications for long routine cases but also on driving home post-night shift. There is a need for further research on individual body clock, mental performance of anaesthetists and whether the decline in performance translates to harm.

There are many variables involved in sleep deprivation and mental performance. Previous studies used different methodologies, had smaller numbers of participants, different neurocognitive tests used, and most did not account for the effects of individual circadian rhythm, the different working conditions, and hours (8, 38, 39, 40). A limitation of our study was that the pre-night shift test was done towards the end of the circadian dip, which could have resulted in lower-than-expected control test scores. This, and the different methodologies of other studies could have accounted for the findings in this study. This study was contextual and the results may not be generalisable to other populations.

Previous studies using neurocognitive tests only investigated registrars at a specific level of training (8, 38, 41), whereas this study tested registrars at all levels of training. Puri et al (39) compared the mental performance of junior and senior anaesthetists and found no difference. It must be stated that the same anaesthetists were not tested pre- and post-night shift, which could explain the difference in the findings (39). A strength of this study was that the same anaesthetists were tested pre- and post-night shift. Furthermore, it was also shown that fourth-year registrars performed significantly better than first-year registrars who had longer post-night shift scores in the Stroop Colour and Word Test and the Trail Making Test. Lewis et al (41) also found that senior doctors answered more questions correctly and more confidently than juniors and were better able to assess their abilities when sleep-deprived (41). This leads to the assumption that shift workers may learn to overcome and adapt to the deleterious cognitive effects of sleep deprivation over time.

Each country and hospital has unique challenges that determine the patient to anaesthetist ratio and the duration of working hours. The Association of Anaesthetists of Great Britain and Ireland (42) recommends prophylactic pre-night shift naps and naps during night shift not exceeding 90 minutes (42). There are no such recommendations for South African registrars. In this study, the majority of registrars (54%) did not nap before coming to work, however, 60% of registrars were able to take a 60-minute nap during the night shift. Further registrar education on the benefits of prophylactic pre-night shift naps could be helpful, in order to facilitate good sleep hygiene.

The Wits Anaesthesia Wellness Committee can play an important role in not only educating registrars on sleep hygiene, but in encouraging registrars to assess and be aware of their fatigue levels and relieve each other where possible. Interventions such as incident monitoring can be implemented with quarterly feedback sessions from registrars. Further studies in other institutions may contribute to the body of knowledge to inform future guidelines.

Conclusion

Wits anaesthesia registrars were able to preserve speed and memory recall but committed more attentional errors post-night shift when engaged in a prolonged and monotonous task. The majority of registrars did not show an association between body clock type and mental performance except for the evening body clock type group (10%), who made more errors during the Continuous Performance Test.

Conflict of interest

The authors declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this paper.

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Section 4: Proposal

Pre- and post-night shift mental performance of registrars in a department of anaesthesiology.

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4.1 Introduction and problem statement

Sleep is a reversible state of unconsciousness which is regulated by the circadian rhythm (1, 2). This physiological regulator is responsible for the sleep-wake cycle. Individual variations in circadian rhythms have been attributed to different expressions of genes coding for this diurnal rhythm (3). Sleep homeostasis is the balance between sleep need (7 – 9 hours every 24 hours) and sleep debt (4). When sleep homeostasis is disrupted and an adult gets inadequate sleep, they develop an increased need to sleep. This is seen by an increased tendency to sleep (sleepiness) and a lack of mental focus as a result of a decline in physical and mental performance (fatigue) (5). If sleep homeostasis is not restored, a cumulative sleep debt occurs and if that is not repaid, sleep deprivation occurs (2).

The consequences of sleep deprivation are biopsychosocial. Sleep deprivation has been linked to the activation of the sympathetic nervous system resulting in an acute release of harmful oxygen free radicals, which can later lead to chronic diseases such as diabetes and hypertension (6, 7). Sleep deprivation increases mood disorders such as anxiety and depression and its disruption of the sleep-wake cycle and the circadian rhythm has been shown to cause a decline in mental performance (8). In a healthy adult, sleep deprivation has been found to be associated with a decline in mental performance (9). The need for sleep is evident as sleep deprivation has been shown to cause psychological disturbances similar to those seen in people with a blood-alcohol level above 0.05% (10).

The hazardous effects of sleep deprivation have been studied in shift workers such as nurses, doctors, pilots, and trucks drivers. Long work hours, consecutive night shifts and inadequate rest periods have been shown to cause chronic shift work disorder, which is a result of protracted sleep deprivation (11, 12). Fatigue-related human errors are a result of microsleep, inattention and decreased mental performance (2, 13).

Mental performance comprises vigilance, psychomotor and executive cognitive functions, including but not limited to memory, calculation and logical reasoning (14). Anaesthetists are required to preserve intuitive and analytical processes, as their decision-making process must result in rapid decision-making and action.

Mental performance in anaesthetists has been characterised as employing non-technical skills and has been tested using neurocognitive tests, technical skills, and simulation labs (15). It has been shown that both technical and non-technical skills are affected by sleep deprivation (16–18).

Night shifts are an essential and inescapable part of healthcare provision and possibly the most physically draining aspect of a registrar's training. The South African Society of Anaesthesiologists suggests that a night shift duty of more than 17 hours must be discouraged (19). In the Department of Anaesthesiology at Wits, registrars are contractually obligated to work 52 – 80 hours of overtime per month, which amounts to approximately five night shifts per month (20). However, in practice, some registrars report working up to seven-night shifts a month (21). Most registrars report being fatigued throughout their training programme (22).

The fatigue levels of the registrars in the Department of Anaesthesiology at Wits as a result of sleep deprivation has been determined. Sanders et al (22) showed that 79.4% of anaesthetists admitted to microsleeps whilst on night shift and 57.9% admitted to daytime microsleep. The results showed that 48.6% perceived making fatigue-related medical errors, 41.1% reported fatigue-related percutaneous injury and 94.4% feared having motor vehicle accidents, post-night shift (22). The authors concluded that Wits anaesthetists are fatigued, and not only pose a risk of harm to themselves but also to their patients and others. Thus, there is a need to quantitatively assess the effects of sleep deprivation on the level of mental performance in registrars. The results could be used to alleviate or confirm the fatigued registrars fears of making errors during task completion.

4.2 Aim and objectives

4.2.1 Aim

The aim of this study is to compare the pre- and post-night shift mental performance of registrars in the Department of Anaesthesiology at Wits using three neurocognitive tests namely the Stroop Colour and Word Test (23), the Trail Making Test (24) and the Continuous Performance Test (25).

4.2.2 Objectives

The primary objectives of this study are to**:**

- compare the pre- and post-night shift mental performance of registrars using three neurocognitive tests
- describe the registrars body clock using the Morningness-Eveningness Questionnaire by Horne and Ostberg (26)

The secondary objective of this study is to compare neurocognitive test scores against their body clock type.

4.3 Research assumptions

The following definitions will be used in this study.

Anaesthetist: any qualified doctor working in the Department of Anaesthesiology including interns, medical officers, registrars and consultants.

Registrar: a qualified doctor who is registered with the Health Professional Council of South Africa as a trainee anaesthetist

Night shift: a defined time period specific to after-hour work in the Department of Anaesthesiology. The duration of night shifts at the affiliated hospital is:

Chris Hani Baragwanath Academic Hospital	16 hours
Charlotte Maxeke Johannesburg Academic Hospital	15.5 hours
Rahima Moosa Mother and Child Hospital	15.5 hours
Helen Joseph Hospital	15.5 hours.

Mental performance: is composed of vigilance, psychomotor and executive cognitive functions, including but not limited to memory, addition and logical reasoning (14). Mental performance and cognitive function are used interchangeably in the literature. Mental performance will be used in this study.

Morningness-Eveningness Questionnaire: a self-assessment questionnaire developed by Horne and Ostberg, which then differentiates the evening phenotype from morning phenotype by assessing the effect of individuals' circadian rhythm (26).

Body clock: the internal biological circadian rhythm that regulates the timing of sleepiness and wakefulness throughout the day (12).

Stroop Colour and Word Test: a neurocognitive test used to test simple and complex attention, executive problem-solving, abstract reasoning and self-regulation. It was developed by John Ridley Stroop in 1935 (27). Stroop observed that individuals read words faster than they could name and identify a colour. Participants are required to name the colour of the font of an incongruent word. This interference causes the naming of the colour to take longer and participants are more prone to errors (28).

Trail Making Test: a neurocognitive test developed by Partington in 1938 used to test attention, working memory, psychomotor speed and ability to modify and implement a plan of action (29, 30). The Trail Making Test consists of two parts. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the circles numbered 1 – 25 in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L). A number must be joined to a letter in order for example, 1 and A, 2 and B. Errors will increase the completion time of the test.

Continuous Performance Test: a neurocognitive test used to measure sustained attention, vigilance and impulsivity. It was developed in 1956 by Beck et al (25). Instruction will be given, for example, "Do not respond when you see a cat." Attention span is the measure of the two types of errors: errors of commission, (impulsive touching of the cat) and errors of omission (failure to touch any animal other than the cat).

4.4 Demarcation of study field

The study will be conducted in the Department of Anaesthesiology, Faculty of Health Sciences of the University of the Witwatersrand. The staff complement of the department is 74 consultants, 112 registrars, and 22 medical officers. The following core hospitals are affiliated to the department’s training platform will be used in the study.

- Charlotte Maxeke Johannesburg Academic Hospital is a 1 200-bed central hospital with 23 theatres. On average 23 000 cases are done annually
- Chris Hani Baragwanath Academic Hospital is a 2 888-bed central hospital with 25 theatres. On average 65 000 cases are done annually
- Helen Joseph Hospital is a 500-bed regional hospital with seven theatres. On average 6 000 cases are done annually
- Rahima Moosa Mother and Child Hospital. A 338-bed regional hospital with five theatres. On average 6 600 cases are done annually

4.5 Ethical considerations

The study will be conducted in accordance with the Declaration of Helsinki (31) and the South African Good Clinical Practice Guidelines (32). Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical) and the Graduate Studies Committee of the University of the Witwatersrand. Permission to conduct the research was obtained from the Head of the Department of Anaesthesiology (Appendix 1).

Registrars will be approached in advance and the study will be explained to them. Those that agree will be given an information letter (Appendix 2) and will be asked to sign consent (Appendix 3) to take part in the study. Consenting registrars will be asked to refrain from consuming caffeinated beverages two hours prior to the study. The duration of the study is approximately 40 minutes pre-night shift and 20 minutes post-night shift and will consist of completing a questionnaire and three neurocognitive tests.

Data will be collected using a study number. A separate list with the participants’ study number and name will be generated separately. The neurocognitive test applications email the results to a preloaded researcher email or a copy of the result is saved on the app using the study number. Results will be made known to participants at the end of the study. The researcher and supervisors will have access to the data. Data will be stored electronically on a password-protected database for six years after completion of the study. Results will be shared with the Head of Department and the Wits Anaesthesia Wellness Committee. Should the results show a decline in mental performance, informative posters will be made to educate anaesthetists on how to mitigate the consequences of sleep deprivation. These posters will be placed in strategic areas in the departments of the various hospitals that are part of the Wits Anaesthesia Department.

4.6 Research methodology

4.6.1 Research design

A prospective, contextual and comparative research design using convenience sampling will be followed in this study.

A prospective study is when a population is selected and studied by a researcher (33). Data will be collected on the day of the study and the results will be analysed.

A contextual study occurs when research is done within a specific study group (34) such as registrars working in the Department of Anaesthesiology at Wits.

A comparative study occurs when groups are compared to an independent variable (33). In this study, the results of the mental performance pre-night shift (rested registrar) will be compared to the post-night shift (sleep-deprived) results. The pre-night shift results will be taken as the control.

4.6.2 Study population

The study population consists of all registrars working in the Department of Anaesthesiology.

4.6.3 Study sample

Sample size

All registrars that are pre- and post-night shift will be invited to participate in the research. Sample size was calculated using a study by Rollison et al (34). This study showed a pre-night shift mean score of 25.6 and a post-night shift mean score of 25.4 for the Continuous Performance Test with a pre- and post-night shift difference of effect size of 0.2. Assuming a 80% power, 5% significance level (95% confidence level) and a high pre- and post-night shift test score correlation of 0.9, the minimum sample size required for the study was 42 registrars. For this study, a margin of error of 5% and a 95% confidence level was assumed and a sample of fifty registrars representing 45% of the registrar population were enrolled, giving a power of >90%.

Sampling method

In this study, a convenience sampling method will be used. Convenience sampling is a sampling technique where participants are selected based on their ease of availability and accessibility to the researcher (35). Registrars that are pre- and post-night shift were included.

Inclusion and exclusion criteria

The inclusion criteria for this study are:

- all registrars working in the Department of Anaesthesiology
- all registrars who consent to take part in the study.

The exclusion criteria in this study are:

- registrars with known medical sleep disorders
- registrars on medication which depresses or stimulates the central nervous system
- registrars with known attention deficits such as attentional-deficit/hyperactivity disorder
- registrars who have consumed coffee or energy drinks less than two hours prior to data collection.

4.6.4 Data collection

Data will be collected on different days during the data collection period. The study will be conducted at Chris Hani Baragwanath Academic Hospital, Charlotte Maxeke Johannesburg Academic Hospital, Helen Joseph Hospital and Rahima Moosa Mother and Child Hospital. The registrars will be invited to the meeting rooms of their respective hospitals. The meeting rooms will be well-lit, quiet and there will be minimal distractions and a “Do not disturb” sign on the door. The study will take place approximately from 15:00 – 15:40 and from 07:00 – 07:20. These times were chosen to avoid the circadian dips and peaks in mental performance. The times are also convenient as they are close to shift change. Mental performance is linked to the diurnal variation of the circadian rhythm. Mental performance fluctuates during the course of the day as it is linked to the diurnal variation of the circadian rhythm. It declines from 03:00 – 07:00 and from 13:00 – 14:00. Peaks in mental performance occur from 08:00 – 13:00 and 20:00 – 23:00 (2).

The pre-night shift study will take 40 minutes with a practice test and the post-night shift study will take 20 minutes. The data collection tools that will be used consist of a questionnaire and three neurocognitive tests. The questionnaire has two parts, demographics and the Morningness-Eveningness Questionnaire (Appendix 4). The first part of the questionnaire will include the following demographics:

- age, sex, year of registrar training
- duration of sleep pre-night shift
- duration of sleep post-night shift
- use of caffeine or energy drinks during the night (volume and type)
- use of caffeine or energy drinks two hours prior to this study.

The second part of the questionnaire will be the seven-minute Morningness-Eveningness Questionnaire developed by Horne and Ostberg (26). This innate body clock is gene-dependent and results in individual differences in sleep, vigilance and response to stimulants. The 19 questions aim to determine if the mental performance of the participant is highest during the morning (early bird) or in the evening (night owl). The scores range from 16 – 86. Scores of 59 and above indicate “morning type” and scores of 41 and below indicate “evening type”. The “intermediate types” are those who score between 42 – 58 (26).

The three neurocognitive tests that will be used are validated and permission to use the tests was granted from the developers (Appendix 5). The tests will be downloaded onto electronic tablet devices (Apple iPad™). Each test provides a practice test and registrars will be allowed to ask questions before and after the commencement of the test.

The Stroop Colour and Word Test is used to test simple and complex attention, executive problem-solving, abstract reasoning and self-regulation. It was developed by John Ridley Stroop in 1935 (27). Bajal et al (23) developed a Stroop smartphone app to screen for cognitive impairment as a result of minimal hepatic encephalopathy. The Stroop smartphone app was found to fulfil the criteria for a neurocognitive test (35). The validation cohort showed 90% specificity and 78% sensitivity (23). The app was found to be reliable, valid, brief and suitable to screen for minimal hepatic encephalopathy. Participants are required to name the colour of the font of an incongruent word or symbol. This interference causes the naming of the colour to take longer and participants are more prone to errors. The duration of the test is user-dependent but most complete it in less than three minutes. The app has not been validated on medical or other populations (23).

The Trail Making Test was developed by Partington in 1938 and used to test attention, working memory, psychomotor speed and ability to modify and implement a plan of action (8, 29). The Trail Making Test has been seen to be sensitive to sleep deprivation, as it has shown poor scores in post-night shift anaesthetists (8). It has been linked to decreased mental performance in subjects that are sleep-deprived (36, 37). This makes it a suitable test for anaesthetists. The Trail Making Test app developed by Simolabs will be used. The Trail Making Test consists of two parts. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the circles numbered 1–25 in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L). A number must be joined to a letter in order for example, 1 and A, 2 and B. The testing time is user dependent and errors will increase the completion time. The test is abandoned after five minutes, but most complete the test in less than three minutes (24).

The Continuous Performance Test is a test used to measure sustained attention, vigilance and impulsivity. It was developed in 1956 (39). Various forms of this test are available, the Visual Attention Test will be used in this study. This test was developed by the New York City Traumatic Brain Injury Centre. The test lasts seven minutes and the results are grouped into errors of commission and errors of omission. Instruction will be given, for example, do not respond when you see a cat. Attention span is the measure of the two types of errors. Errors of commission (impulsive touching of the cat) and errors of omission (failure to touch any animal other than the cat). In sleep-deprived subjects, mean error scores have been shown to be elevated and correct response scores were lowered (40). Reaction time has been shown to decline in order to preserve the accuracy of response, at the expense of speed (41).

4.6.5 Data analysis

A Microsoft Excel spreadsheet will be used to capture data from questionnaires and neurocognitive tests. The data will be analysed in consultation with a biostatistician using Stata14 (StataCorp, USA). Categorical variables will be described using frequencies and percentages. Pre-night shift scores of each participant will act as the control (measured in time). The post-night shift score will be compared to the control. A paired t-test will be used as long as the assumptions for normality have been met. If the assumption is not met, the non-parametric Wilcoxon signed-rank test will be used. Comparisons between groups was done using the Kruskal Wallis test. A p-value of <0.05 will be considered to be statistically significant.

4.7 Significance of the study

Sleep deprivation has been linked to negative psychological manifestations such as depression, anxiety and burnout in shift workers (6, 9, 42). Sleep deprivation in the workplace results in sleepiness, fatigue and a decline in mental performance which can negatively impact the anaesthetists and their patients (13, 38).

Sanders(22) described the perceptions and effects of sleep deprivation using the validated Epworth Sleepiness Scale. The findings showed that all anaesthetists who participated in the study complained of insufficient sleep due to long working hours that included night shift.

The results of this study will provide data, which when combined with Sanders' (22) study may assist with the formulation of tools such as mandatory breaks and rest periods during night shifts as a way of mitigating the consequences of sleep deprivation.

4.8 Validity and reliability of the study

Validity refers to the “degree to which the study measures what it was intended to measure” and reliability represents “ the consistency of the measure achieved” (43).

The validity and reliability of the study will be ensured through the use of:

- using an appropriate study design
- determining the sample size which was determined in consultation with a biostatistician
- using the published and validated Morningness-Eveningness Questionnaire
- using validated neurocognitive tests which are sensitive to sleep deprivation
- registrars performing a practice test before the commencement of the test
- the researcher being available to answer any questions
- all tests being done by one researcher
- data being analysed in consultation with a biostatistician.

4.9 Potential limitations

The research design chosen has the following potential limitations.

- The study will be done contextually in the Department of Anaesthesiology, therefore the results may not be generalisable to other anaesthesiology departments.
- The participants will be required to arrive at the testing centres at 15:00 pre-night shift and at 07:00 post-night shift. This could be a deterrent as the participants usually arrive at 16:00 and leave at 07:30.

4.10 Project outline

4.10.1 Time frame

	Mar 2019	Apr 2019	May 2019	Jun 2019	July 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019
Proposal preparation										
Literature review										
Proposal submission										
Ethics approval										
Postgraduate approval										
Data collection										
Data analysis										
Draft article										
Submission										

4.10.2 Budget

Item	Price per page	Number of pages	Copies	Total
Proposal	R 1	34	6	R 204
Postgrad form	R 1	2	6	R 12
Consent forms	R 1	1	50	R 50
Information letter	R 1	1	50	R 50
Questionnaire	R1	3	50	R 150
Grand Total				R 466

The Department of Anaesthesiology will bear the cost of printing and paper for the proposal, ethics and postgraduate approvals. Three electronic tablet devices (Apple iPad™) will be provided by the researcher and any additional costs will be incurred by the researcher. The neurocognitive test applications were freely available on Google Play. No additional funding will be required.

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4.12 Appendices

Appendix 1: Permission letter from HOD

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

WITS UNIVERSITY

Department of Anaesthesia – University of the Witwatersrand

7 York Road, Parktown, 2193 South Africa • Telegrams "Witsmed" • Telephone (011) 488-4344 • Fax (011) 488-4343

Department of Anaesthesia
Area 361
Charlotte Maxeke Johannesburg Academic Hospital

Tel: 011 488-4344

05 April 2019

Subject: **Permission to collect data from Department of Anaesthesia**

To whom it may concern,

This letter stands to affirm that I, Dr PMV Motshabi, grant permission to Dr Hilda Masvikwa, HPCSA number MP 0769215, to collect data in Department of Anaesthesiology at University of Witwatersrand for her study "Pre- and post-night shift mental performance of registrars in a department of anaesthesiology".

The approximate time frame will be, but not limited to, the months of May to September 2019, until her sample size is obtained. The information obtained from the data will be used for Dr Masvikwa research study for her Masters in Medicine only, and will include information and data relevant to her study.

Yours sincerely,

Dr Palesa Motshabi
Academic Head: Department of Anaesthesia
Head of Clinical Unit: Cardiac Anaesthesia

Tel: +27 (0)11 488 4344
Cell: 083 432 1994
Email: palesa.motshabi@wits.ac.za
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WITS UNIVERSITY | WITS SCHOOL OF CLINICAL MEDICINE | FACULTY OF HEALTH SCIENCES

Charlotte Maxeke Johannesburg Academic Hospital, 6th Floor, Area 361/16, Jubilee Road, Parktown, Johannesburg

APPENDIX 2: INFORMATION LETTER

Pre- and post-night shift mental performance of registrars in a department of anaesthesiology.

Dear Colleague,

Hello, my name is Hilda Tsungayi Masvikwa. I am a registrar in the Department of Anaesthesiology and am currently busy with my M Med. I would like to invite you to participate in my research. The aim of this study is to compare the pre- and post-night shift mental performance of the registrars in the Department of Anaesthesiology at Wits using neurocognitive tests. You will also complete a Morningness-Eveningness Questionnaire, which will describe their individual circadian rhythm (body clock).

This two-part study that will be conducted in the meeting rooms of your respective hospitals. The study will be conducted at 15:00 and at 07:00 and will take approximately 40 minutes pre-night shift and 20 minutes post-night shift to complete. The study will require you to complete a questionnaire which will consist of demographics and a body clock questionnaire. and three short neurocognitive tests will done on iPads, which I will supply. No identifying information will displayed and you will be given a study number. After completion of the study, the questionnaire will be placed in a sealed collection box and the results of the neurocognitive tests will be downloaded and secured on a password protected database. Only my supervisors and I will have access to the data. If you wish, the data will be made available to you after the completion of the study.

Participation is voluntary and should you agree to participate, you will be required to sign a consent form. You may withdraw at any time and you will not be required to give reasons nor will you be discriminated against. Please refrain from consuming any caffeinated beverages two hours prior to both tests. After completion of the study, please do not discuss the study with any of your colleagues until the completion of the data collection period.

Participants will have to arrive at work 60 minutes earlier than usual. However, the results may help to provide insight into your mental performance while on night shift. This information will be shared with the Head of Department and the departments' Wellness Committee and which may result in improving your experience of night shifts.

This study has been approved by the Human Research Ethics Committee (Medical) and the Graduate Studies Committee of Wits. Should you require more information, or wish to contact me regarding this study, my mobile number is 079 879 2364. You may also contact:

- Professor CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of the Witwatersrand, on telephone : 011 717 2301, e-mail: Clement.Penny@wits.ac.za
- Committee Secretariat: Ms. Z Ndlovu or Mr. Rhulani Mkansi, telephone : 011 717 2700/1234, or e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za.

Thank you for taking the time to read this letter.

Yours sincerely

Hilda Masvikwa

APPENDIX 3: PARTICIPANT CONSENT

Pre- and post-night shift mental performance of registrars in a department of anaesthesiology

1. I ………………………………………. agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

2. If I do consume caffeinated beverages, I will do so only until two hours prior to the testing.

3. I was given time to ask questions and found any answers given to me to be reasonable and satisfactory.

4. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment.

5. Participation will not cost me anything but my time.

6. I understand that even if I initially consent to take part in the study, I may withdraw at any time and would not be required to give reasons. If that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained.

7. If I require further information, I have been given a range of contact details, listed below.

…………………………………… (signature)

…………………………………… (date)

Contact details:

HT Masvikwa Researcher, cell phone: 079 879 2364 or by e-mail: 0603325P@students.wits.ac.za

Professor CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of the Witwatersrand, on telephone : 011 717 2301, or my e-mail: Clement.Penny@wits.ac.za

Ms. Z Ndlovu or Mr. Rhulani Mkansi, Committee Secretariat, telephone : 011 717 2700/1234, or e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za

APPENDIX 4

PART A: DEMOGRAPHICS- Please tick the appropriate box

1. Age (Years)

25 – 29	30 – 34	35 – 39	40 – 44	> 45

2. Gender

Male	Female

3. After waking up this morning, how many additional hours of sleep have you had in preparation for your night shift?

……….. Hours

4. How many hours of sleep did you have during this night shift?

………. Hours

5. Have you had any caffeine or energy drinks during the night? If yes, state the Type and volume.

Type (s)	
Volume (ml)	

6. Have you had caffeine or energy drinks two hours prior to this study?

Yes	
No	

7. Year Of registrar Training

1st	2nd	3rd	4th

Part B: Activity – late to bed or early to rise? Which one are you?

Your mental performance is linked to your individual circadian rhythm. Understanding your body clock will help you understand which times of the day you are more productive and what times are best for you to sleep.

Instructions

A. Read each question carefully and answer all questions in numerical order

B. Do NOT go back and check your answers

C. Tick the box next to the answer which best describes you

Questions

1. If you were entirely free to plan your day, what time would you wake up?

05:00 – 06:29		06:30 – 07:44		07:45 – 09:44	
09:45 – 10:59		11:00 – 11:59		Midday – 05:00	

2. If you were entirely free to plan your day, what time would you go to bed.

20:00 – 20:59		21:00 – 22:14		22:15 – 00:29	
00:30 – 01:44		01:45 – 02:59		03:00 – 20:00	

3. If there is a specific time at which you have to get up in the morning, to what extent do you depend on being woken up by an alarm clock?

Not at all dependent		Slightly dependent	
Fairly dependent		Very dependent	

4. **How easy do you find it to get up in the morning (when you are not woken up unexpectedly)**

Not at all easy		Not very easy	
Fairly easy		Very easy	

5. **How alert do you feel during the first half hour after you wake up in the morning?**

Not at all alert		Slightly alert	
Fairly alert		Very alert	

6. **How hungry do you feel during the first half-hour you wake up in the morning?**

Not at all hungry		Slightly hungry	
Fairly hungry		Very hungry	

7. **During the first half-hour after you wake up in the morning, how tired do you feel?**

Very tired		Fairly tired	
Fairly refreshed		Very refreshed	

8. **If you have no commitment the next day, what time would you go to bed compared to your usual bedtime?**

Seldom or never later		Less than one hour later	
One to two hours later		More than two hours later	

9. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 07:00 – 8:00 Bearing in mind nothing but your own internal "clock", how do you think you would perform?

Would be in good form		Would be in reasonable form	
Would find it difficult		Would find it very difficult	

10. At what time of day do you feel you become tired as a result of the need for sleep?

20:00 – 20:59		21:00 – 22:14		22:15 – 12:44	
00:45 – 01:59		02:00 – 03:00			

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last for two hours. You are entirely free to plan your day. Considering only your internal "clock", which ONE of the four testing times would you choose?

08:00 – 10:00		11:30 – 13:00	
15:00 – 17:00		19:00 – 21:00	

12. If you got into bed at 23:00, how tired would you be?

Not at all tired		A little tired	
Fairly tired		Very tired	

13. For some reason, you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following are you most likely to do?

Will wake up at the usual time, but will NOT fall back asleep	
Will wake up at the usual time and will dose thereafter	
Will wake up at the usual time but will fall asleep again	
Will NOT wake up until later than usual	

14. One night you have to remain awake between 04:00 – 06:00 in order to carry out a “night watch”. You have no commitments and the next day. Which ONE of the alternatives will suit you best?

Would NOT go to bed until watch was over	
Would take a nap before and sleep after the “night watch”	
Would take a good sleep before and nap after the “night watch”	
Would sleep only before watch	

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your internal “clock” which ONE of the following times would you choose to do the work?

08:00 – 10:00		11:00 – 13:00	
15:00 – 17:00		19:00 – 21:00	

16. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 22:00 – 23:00. Bearing in mind nothing but your own internal “clock”, how do you think you would perform?

Would be in good form		Would be in reasonable form	
Would find it difficult		Would find it very difficult	

17. Suppose you went to work for a five hour day and that your work was enjoyable and interesting. In which of these time slots would you start your day.

04:00 – 07:59		08:00 – 08:59		09:00 – 13:59	
14:00 – 16:59		17:00 – 03:59			

18. At what time of the day do you think that you can reach your “feeling best” peak?

05:00 – 07:29		08:00 – 09:59	
10:00 – 16:59		17:00 – 21:59	

19. One hears about “morning” and “evening” types of people. Which ONE of these types do you consider yourself to be?

Definitely a “morning” type	
Rather a “morning” type than an “evening” type	
Rather more an “evening” type than a morning type	
Definitely an “evening” type	

Thank you for answering these questions.

APPENDIX 5 PERMISSION TO USE GOOGLE PLAY APPLICATIONS BY THE DEVELOPERS OF THE THREE NEUROCOGNITIVE TESTS.

APPENDIX 5.1 ENCEPHALAPP STROOP TEST

From Hilda Masvikwa • hilda.masvikwa@gmail.com
To encephalapp@gmail.com
Date 13 Mar 2019, 17:08
See security details

Dr Jasmohan Bajaj

My name is Dr Hilda Masvikwa, and i am a 2nd year anaesthesiology registrar at the University of Witwatersrand in South Africa. I am doing my mmed on " Comparing the cognitive performance of anaesthetists pre and post night shift, using neurocognitive tests"

I would like to find out the process required for me to get authorisation to use your Encephalapp stroop test for my research.

Kind regards
Dr Hilda Masvikwa

J Jasmohan Bajaj 14 Mar
to me

From Jasmohan Bajaj • encephalapp@gmail.com
To Hilda Masvikwa • hilda.masvikwa@gmail.com
Date 14 Mar 2019, 13:31
See security details

Dear Hilda
You can use this App but please make sure that you reference the papers that are in the settings section of the App when you present/publish your research.
Good Luck!!
jas

APPENDIX 5.2

TRAIL MAKING TEST

Dear Simone Sacchi

My name is Dr Hilda Masvikwa, and i am a 2nd year anaesthesiology registrar at the University of Witwatersrand in South Africa. I am doing my mmed on " Comparing the cognitive performance of anaesthetists pre and post night shift, using neurocognitive tests"

I would like to find out the process required for me to get authorisation to use your Trail making test app for my research. Has this app been used on medical doctors to assess cognitive function?

Kind regards
Dr Hilda Masvikwa

H **Hilda Masvikwa** 19 Mar
to ZSimo

Hi Simone

Just following up in my email that i sent to you.

I would like to you your app as part of my research on anaesthesia doctors

Show quoted text

Z **ZSimo Labs** 19 Mar
to me

From ZSimo Labs • zsimolabs@gmail.com
To Hilda Masvikwa • hilda.masvikwa@gmail.com
Date 19 Mar 2019, 12:05
See security details

Hello Hilda,

Yes, off course you can use my app in your research, there is no need of my authorization to do it.
Yes, my app has been used in others scientific research (from time to time authors write me to let me know).

Sorry for the delay in responding you.

Regards,
Simone

APPENDIX 5.3

CONTINUOUS PERFORMANCE TEST: VISUAL ATTENTION TEST

H

Hilda Masvikwa 20 Mar

to shrenk85

From Hilda Masvikwa • hilda.masvikwa@gmail.com

To shrenk85@gmail.com

Date 20 Mar 2019, 11:48

See security details

Hi

My name is Dr Masvikwa,anaesthetist in South Africa, at the University of Witwatersrand. Im wanting to do research on my colleagues on congitive function after night call.i would like to ask permission to use your app.

I would also want to know if
1. The app has been validated
2. Is there an email function to send results of each test
3. Any references used in the formation of your app

Hope to hear from you soon

Kind regards

H

Hilda Masvikwa 15:53

to Julia

Hi Julia

Hope you are well? I am following up on the two emails i had previously sent asking permission to use your application for my research project

Kind regards
Hilda

Show quoted text

APPENDIX 5.4

CONTINUOUS PERFORMANCE TEST: VISUAL ATTENTION TEST

NYC Traumatic Brain Injury Center

Check your attention span with our free "Visual

Attention Test" App. on your iPhone or Android

This continuous performance test was designed by our neuroscience team and enables you to measure your attention span with your iPhone or Android device, in the comfort of your home. This app allows you to monitor your progress if you start any treatment, cognitive exercise or neurofeedback program to improve your concentration power.

The neurocognitive tests are freely available from the Google Play application store. Consent for use is implied, however, permission was sort from all three developers and currently two of the three have consented. Formal approval from the developer of the Continuous Performance Test is still pending but supporting documents for this test have been added.

APPENDIX 6 LETTERS OF CO-OPERATION AND COLLABORATION OF THE WITS PSYCHOLOGY DEPARTMENT.

Psychology
School of Human & Community Development
Private Bag 3, Wits 2050, South Africa
Telephone: +27 11-717-4500/2/3/4. Fax: +27-11-717-4559

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Dr Hilda Masvikwa - Wits Anaesthesia Registrar

To whom it may concern

I was invited by Dr Masvikwa to discuss her research proposal titled- *Pre- and post night shift neurocognitive function of Wits anaesthesia registrars*. Dr Masvikwa proposes utilizing digital versions of the Stroop Colour Word Test, Trail Making Test and Continuous Performance Test to gather data and has permission to use these from the developer of the said measures. Automated administration procedures were demonstrated and resultant data files were examined. The chosen tests are uncomplicated to administer with accuracy and speed of response automatically recorded. In the statistical analysis of data it is proposed that participants pre- and post-night shift serve as their own standard of comparison.

With the support of my department, I wish accept Dr Masvikwa's invitation to provide specialized assistance relative to the collection and interpretation of her data should she require this at any stage of her research.

Regards

Enid Schutte

Lecturer : Department of Psychology
E-mail : Enid.Schutte@wits.ac.za
Office : 0117174521
Cell : 0829206731

APPENDIX 6.2 LETTERS OF CO-OPERATION AND COLLABORATION OF THE WITS PSYCHOLOGY DEPARTMENT

Department of Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 45

12 June 2019

Re: Research project of Dr Hilda Masivikwa

To whom it may concern,

Dr Masivika approached our Department as she needed a neuropsychologist to be part of her research study titled: Pre- and post-night shift neurocognitive function of Wits anaesthesia registrars. Ms Enid Schutte, a colleague from the Psychology Department, met with Dr Masivikwa to discuss her proposed research. Dr Masivikwa proposes utilizing digital versions of the following neuropsychological tests: Stroop Colour Word Test, Trail Making Test and Continuous Performance Test, and has permission to use these from the developer of the said measures. Administration procedures were demonstrated to Ms Schutte, who was invited to provide specialized assistance relative to the collection and interpretation of this data for the project. I support Ms Schutte's decision to accept this invitation and wish Dr Masivikwa all of the very best in her research.

Yours sincerely,

K. Cockcroft

Kate Cockcroft
Professor
Department of Psychology
School of Human and Community Development
University of the Witwatersrand
Tel: 011 7174511
Email: kate.cockcroft@wits.ac.za

Section 5: Annexures

5.1 Ethics approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr Hilda Tsungayi Masvikwa

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190440

NAME: (Principal Investigator)	Dr Hilda Tsungayi Masvikwa
DEPARTMENT:	Anaesthesiology Chris Hani Baragwanath and Charlotte Maxeke Johannesburg Academic Hospitals, Helen Joseph Hospital Rahima Moosa Mother and Child Hospital
PROJECT TITLE:	Pre-and post-night shift mental performance of registrars in a department of anaesthesiology
DATE CONSIDERED:	2019/4/26
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Juan Scribante, Helen Perrie & Thenjiwe Hlongwane
APPROVED BY:	Dr N Naran, Deputy Chairperson, HREC (Medical)
DATE OF APPROVAL:	08/08/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized
to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **April** and will therefore be due in the month of **April** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

5.2 Graduate studies approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

25 July 2019
Person No: 0603325P
PAG

Dr HT Masvikwa
Box 652555
Benmore
2196
South Africa

Dear Dr Hilda Masvikwa

Master of Medicine in Anaesthesia: Approval of Title

We have pleasure in advising that your proposal entitled *Pre and post-night shift mental performance of registrars in a department of anaesthesiology* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

5.3 Turnitin report

0603325p:Introduction.docx

ORIGINALITY REPORT

16%	7%	10%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Gregory, P., and M. Edsell. "Fatigue and the Anaesthetist", Continuing Education in Anaesthesia Critical Care & Pain, 2013. Publication	1%
2	Submitted to University of Witwatersrand Student Paper	1%
3	www.sleepmedres.org Internet Source	1%
4	Haydee C. Cochrane. "Neuropsychological Outcomes in Randomized Controlled Trials of Antiepileptic Drugs: A Systematic Review of Methodology and Reporting Standards", Epilepsia, 10/1998 Publication	<1%
5	www.mm3admin.co.za Internet Source	<1%
6	epubs.rcsi.ie Internet Source	<1%
7	Göran Kecklund, John Axelsson. "Health	

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

19th June, 2020

The Chairperson
Graduate Studies Committee
Faculty of Health Sciences
University of the Witwatersrand

Dear Madam,

Re: M Med: **Pre- and post-night shift mental performance of registrars in a department of anaesthesiology**

Dr Hilda Masvikwa, student number: 0603325P, has submitted her research report to Turnitin which revealed a similarity index of 16%. These similarities appear not to be plagiarism but mainly the use of common terminology and phrases specific to the topic of the research.

Yours sincerely,

H C Perrie

Helen Perrie
Supervisor

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